2005 ASHRAE Technology Award

It's in the Details

Engineering for Low Cost and High Efficiency

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The Electronic Arts Phase II building (EAII) serves as the headquarters for Electronic Arts, a video game developer located outside San Francisco. It was completed in 2002. The building is 350,000 ft^2 (32 515 m^2),four stories tall, and includes offices, an atrium, cafeteria, child care center, and auditorium. There is nothing particularly "sexy" about the mechanical system—no thermal storage tanks or ground-coupled heat rejection. Yes, it has many state-of-the-art features such as underfloor air distribution and a primary-only, variable flow, chilled water plant, but this is not why EAII earned an ASHRAE Technology Award.

What is remarkable about EAII is that it is an excellent example of how sound engineering principles and attention to detail can be combined to arrive at a mechanical design that is inexpensive and exceptionally energy efficient. At a time of soaring construction costs (think Silicon Valley during the Dot Com Boom) and skyrocketing energy prices (Anyone remember the California Energy Crisis?), the HVAC construction cost for EAII came in at an astonishingly low \$13.10/ft^2 (\$141/m^2) and the utility bills for the first two years of operation were less than half those of conventional office buildings.

Energy Efficiency

According to a detailed DOE-2 simulation model, this building consumes 39.5% less energy than a standard California energy code compliant building. Per the U.S. Green Building Council's Leadership in Energy and Environmental Design® (LEED) point interpolation table, the building exceeds ANSI/ASHRAE/

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The Electronic Arts Phase II building outside San Francisco exceeds Standard 90.1 by almost 50%.

IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* by almost 50%. The DOE-2 results were used to qualify the building for a $200,000 utility rebate (the maximum possible amount).

Utility data have confirmed that the building is operating exceptionally efficiently. Phase I (two large office buildings completed in 1998) and Phase II (this building) share a single electric utility meter. They are also similar in terms of size, occupancy type, etc. except that most areas of Phase II operate continuously due to the often nocturnal nature of the video game programmers. Despite these extended hours, comparing bills before and after Phase II (assuming that Phase I energy use is roughly constant) demonstrates that Phase II uses about half the electricity as Phase I on a unit area basis. Phase I and Phase II are on separate natural gas meters and Phase II is using about one-third as much gas as Phase I on a unit area basis. Energy usage was low enough to qualify the Phase II building for an EPA Energy Star score of 88 out of 100.

Design Features

The following is a partial list of the energy-efficiency features that account for the exceptional energy performance of the building:

- **Underfloor air-distribution system.** The top three floors are served by an underfloor air distribution system with variable speed fan terminal units for perimeter heating. This system reduces supply fan energy by eliminating much of the supply air duct system and all VAV boxes, improves economizer performance by increasing supply air temperatures, and reduces reheat energy losses by allowing very low minimum airflow setpoints and very warm supply air temperatures.
- **High-efficiency chillers.** Chillers were selected during the design development stage using a life-cycle cost bid process based on detailed DOE-2 energy simulations of multiple chiller options provided by three major chiller vendors. The option with the lowest life-cycle cost consisted of two 315 ton (1108 kW) variable speed driven centrifugal chillers and one 75 ton (264 kW) "pony" screw chiller. The pony chiller improves off-hour plant efficiency since the plant runs continuously to serve a small data center.
- **High-efficiency cooling towers with variable speed driven fans.** As with the chillers, cooling towers were selected using a life-cycle cost performance bid. The towers with the lowest life-cycle cost were propeller draw-through type towers with an efficiency exceeding 75 gpm/hp (6.34 L/s per kW) (at Standard 90.1 rating conditions) and with a 7°F (4°C) approach.
- **High chilled water ΔT.** Coils were selected to provide an average 17°F (8°C) temperature difference. This reduces pump energy costs and first costs (smaller piping, pumps,

pump motors, and variable speed drives).

- **Primary-only, variable flow, chilled water distribution system with variable speed pumps.** This system saves first cost and energy compared to a conventional primary/secondary system.
- **Chilled water differential pressure setpoint reset and temperature setpoint reset.** Chilled water valve position is used to reset in sequence the chilled water differential pressure setpoint and the chilled water supply temperature setpoint. This reduces chiller energy during low load periods and pump energy during all other load conditions.
- **Variable flow hot water distribution with reverse return and multiple distributed risers.**

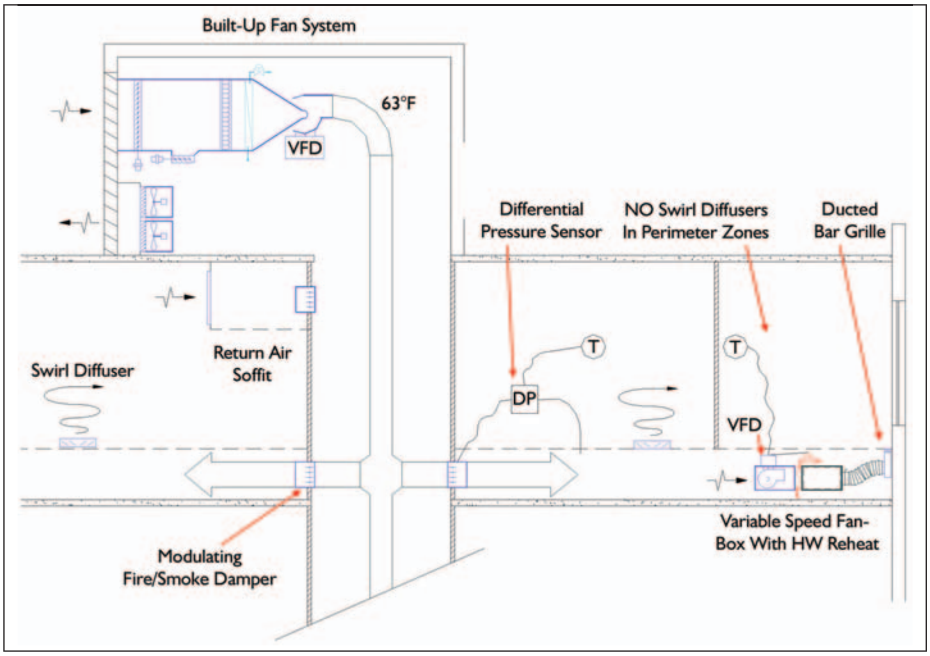

Figure 1: This shows the cascading control loops used to control the underfloor control dampers.

- **Duct static pressure setpoint reset.** Static pressure setpoint for the underfloor central supply fans is reset so that one underfloor static pressure control damper remains nearly wide open. This allows the setpoint to drop at low loads, reducing fan energy by about 50% compared to a fixed setpoint.[1] Similarly, the static pressure for the overhead VAV systems is reset so that one VAV box remains nearly wide open.
- **Underfloor plenum pressure reset.** *Figure 1* shows the cascading control loops used to control the underfloor control dampers. The underfloor plenum on each floor is divided into four isolation areas with underfloor demising partitions. Air is injected into the floor through modulating control dampers (in some cases modulating fire/smoke dampers located at the duct shaft). Average monitored interior zone space temperature is maintained at setpoint by resetting the underfloor static pressure setpoint in the range of 0 in. w.g. to 0.1 in. w.g. (0 Pa to 25 Pa). The control dampers are then modulated to maintain the underfloor static pressure at setpoint. One reason for the cascading control loop is that it maintains the plenum positive relative to the space to prevent perimeter fan terminals from drawing air backwards through the swirl diffusers. Some other underfloor designs require a relatively high fixed underfloor pressure (e.g., 0.1 in. w.g. [25 Pa]) to provide sufficient pressure for perimeter zone cooling dampers. One problem with such an approach is that lightly loaded interior zones can be overcooled. With perimeter variable speed fan terminals and the cascading control loop, this problem is eliminated.
- **Variable speed underfloor fan terminals with ECM motors.** *Figure 2* shows the control sequence for the underfloor fan boxes. One innovative feature of this sequence is that reheat is drastically reduced compared to conventional VAV control. In deadband, the fan is shut off and minimum ventilation is supplied by the plenum pressure pushing air through the fan terminal. In heating mode, the fan runs at minimum speed (about 15%) until the supply air temperature is 130°F (54°C). Only then is fan speed ramped up to 30%. Even at this speed, reheat energy is reduced compared to conventional systems due to the warm primary supply air temperatures (~65°F [~18°C]).
- **Sequenced economizer dampers.** Air handler outside air and return air dampers are sequenced rather than modulated simultaneously to reduce pressure drop through the mixing box during economizer operation.
- **Low-pressure drop return air system with variable speed propeller relief fans.** The return air system has a very low pressure drop since there are no ceilings or return air ductwork (return air is drawn into architectural return air shafts through large grilles at each floor). The first stage of economizer relief is simply to open the motorized backdraft dampers on the relief fans. Trend logs show that the relief fans almost never run even in 100% outdoor air economizer mode.
- **Partially conditioned atrium with radiant heat/cool floor slab and natural ventilation.**
- **Server rooms cooled by VAV boxes instead of fan-coils.** This design takes advantage of economizer free cooling and the higher fan efficiency of central air handlers versus small fan-coils. Normal VAV zones served by the air handler are shut off during unoccupied periods allowing central fans to operate at very low pressure drop, speed, and power to serve 24/7 loads.
- **Commissioning.** Perhaps the most important energy-efficiency feature is the fact that a thorough commissioning process was executed, including a full battery of prefunctional and functional test performed by the contractor followed by several days of functional tests and multiple rounds of post-occupancy trend review performed by the design engineers. These tests were able to confirm that all control sequences were successfully

implemented. *Figure 3*, for example, illustrates that the underfloor duct static pressure reset sequences are working quite well. During this period, the setpoint was reset from 0.9 in. w.g. down to 0.15 in. w.g. (224 Pa down to 37 Pa) based on damper position. The actual static pressure closely tracked the setpoint.

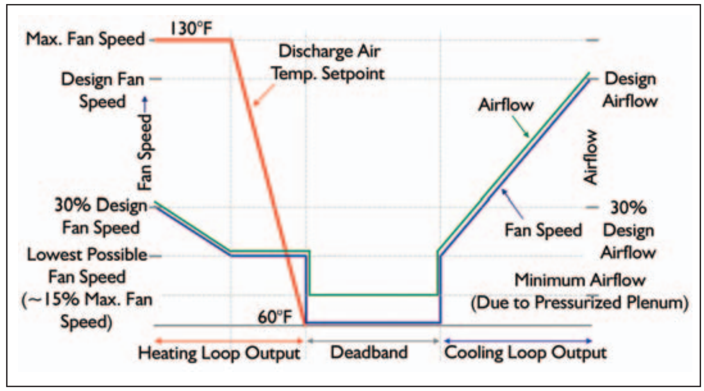

Figure 2: Underfloor fan box control.

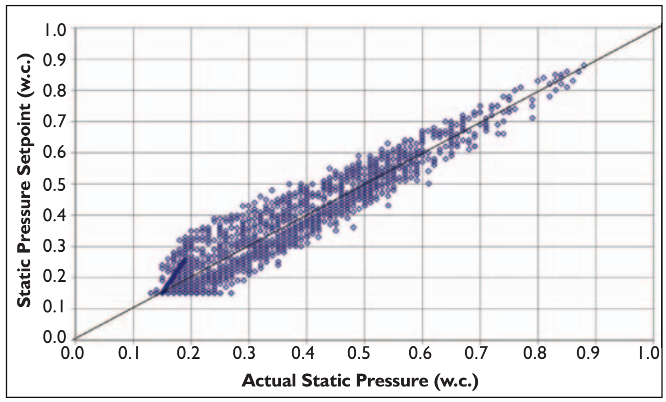

Figure 3: Static pressure setpoint reset.

Cost Effectiveness

Two basic approaches were used to keep mechanical costs down: value engineering and detailed coordination. Value engineering, in this case, meant using sound engineering judgment to eliminate the "little things" that so often add up to big mechanical costs. Here are some examples of value engineering:

- No return air ductwork;
- 24/7 loads served by VAV boxes, rather than computer room AC units;
- Extremely close-coupled chilled water plant. The cooling towers are approximately 15 ft (4.6 m) from the condenser water pumps, which are 5 ft (1.5 m) from the chillers, which are 12 ft (3.7 m) from the chilled water pumps;
- High-temperature differences in both cooling and heating systems, which reduces flow rates. Piping was also sized based on a detailed engineering and life-cycle cost analysis which resulted in piping close to the pumps (where available differential pressures are high) to be significantly smaller than conventional practice.
- Elimination of all manual balancing devices and automatic flow limiting valves in the chilled and hot water systems. Research has shown that two-way control valves are essentially self-balancing, particularly with a reverse-return hot water system.[2]

In addition to engineering judgment, detailed simulation and life-cycle cost analyses were performed on many of the design choices including, chillers, cooling towers, variable speed drives, underfloor fan terminal type, boiler type (condensing, atmospheric or forced draft), boiler flue dampers, and CO_2 controls. One of the options evaluated was the use of distributed hot water risers as opposed to the more common approach of a single central hot water riser with horizontal distribution. According to the mechanical contractor (both options were bid as alternates), the distributed riser approach reduced the first cost by $300,000 compared to a central riser approach.

Detailed coordination meant more than just an "airtight" set of mechanical plans and specifications. It also meant thorough coordination with other trades so that responsibilities were clear and there were no conflicts in the field.

For example, careful coordination with the architect and floor contractor was vital to ensure that the supply riser takeoffs on each floor were exactly lined up with the raised floor pedestals so that no unnecessary duct offsets were required. Coordination also meant maintaining good relationships with the contractors and soliciting and accepting their ideas on how to cut costs and improve quality. The general contractor and the mechanical contractor deserve as much credit as anyone for the success of the project based on their construction skills, management experience and coordination efforts. They did an excellent job of being team players and avoiding the adversarial relationships that too often develop on construction projects. This extra level of coordination and cooperation by the design team and the construction team resulted in a job that was on time and had essentially no mechanical contractor change orders, other than those resulting from owner changes in scope.

The ultimate indicator of the cost effectiveness of the HVAC design was the project cost. The mechanical cost for this project was $6.88/ft^2 ($74.06/m^2) for the core and shell, and $6.22/ft^2 ($66.95/m^2) for the tenant improvements for a total HVAC construction cost of $13.10/ft^2 ($141.01/m^2), which was far less than the cost of typical code-minimum HVAC systems in San Francisco Bay Area office buildings at that time (~ $15/ft^2 to $20/ft^2 [$160/m^2 to $215/m^2] total HVAC construction cost).

Conclusion

The HVAC system design at Electronic Arts II has proven to be energy efficient and cost effective. The success of the project had as much to do with the application of old fashioned ideas like attention to detail, teamwork and follow through as it did with the application of state-of-the-art technology.

References

1. Hydeman, M., J. Stein. 2003. "A fresh look at fans." *Heating/Piping/Air Conditioning Engineering* May.

2. Taylor, S., J. Stein. 2002. "Balancing variable flow hydronic systems." *ASHRAE Journal* 44(10).